**POSSIBLE BACTERIA IN NAKHLA.** D. S. McKay, S. W. Wentworth, K. Thomas-Keprta, F. Westall, E. K. Gibson, Jr. NASA Johnson Space Center Houston TX 77058.

Mars Aqueous Alteration Nakhla contains alteration products in an extensive network of which fill cracks, veins, and void spaces, composed of smectite, although in some cases they are amorphous and gel-like [1,2]. Strong evidence presented by [1] show that these alteration products developed on Mars: some veins are offset by impact faulting of olivine followed by annealing of the olivine, and veins near the fusion crust show partial vesicle development suggesting heating and volatile liberation. The smectite-containing cracks and veins are interpreted as low temperature aqueous alteration on Mars [1]. We have been studying these veins with optical microscopy and high resolution SEM.

Optical Microscope Results Most cracks and veins contain a brownish material, and in some places a fine parallel structure suggestive of smectite. In other areas, no structure is apparent. High magnification (100x objective) study reveals that some of the cracks and void material contain very fine rounded to ovoid particles with a limited size range. embedded within the alteration filling. These fine particles are near the limit of resolution of the optical microscope, and are estimated to be from about 0.25-0.5 micrometers in diameter. Changing the focus shows that they are distributed throughout the 30 micrometer-thick section. The particles are heterogeneously distributed within cracks and among different cracks and voids. They are present in both well-crystallized and amorphous smectite.

SEM Results We have examined a number of small chips of NAKHLA from the sample recently provided by Monica Grady and the British Museum. The chips originated from near the fusion crust (NAKHLA,14) and from the center or interior (NAKHLA, 10). Samples were mounted without washing and were coated with about 3-5 nanometers of platinum for conductivity. They were examined in a JEOL 6340 FEG-SEM and a Philips XL40 FEG-SEM. Identification of vein-filling material between silicate grains is relatively straightforward. Some of this vein-filling material is clearly separating adjacent grains and some is on grain surfaces where it was presumably exposed as the chip cracked along preexisting veins. Textures include distinct networks consisting of straight line segments typical of some well-developed clay textures. Other textures include overlapping shingle-like micrometer plates, again reminiscent of some clay textures.

Another vein texture is a fine-grained or homogenous matrix containing rounded units which are typically 0.2 to about 1 micrometers in diameter (Figs. 1,2). Some of the alteration product surfaces display clear individual particles which are only partially embedded in the matrix or appear to be totally on top of the matrix surface. Intermixed with these particles are fine networks of mostly linear material. Both the sample near the interior and the sample near the fusion crust contain these features. In each set of chips, the rounded units are limited to only a few areas. Many of the obviously altered secondary deposits do not contain any rounded units; some chips contain none at all, while other chips contain only a few sparse patches making up a very small percentage of the area examined.

The composition of the alteration product as analyzed by EDS is typically Mg, Si, Fe, and O. Aluminum is absent or very low. The ratio of Si to the other cations varies considerably; some areas contain very high silica. In most cases, the spherical units appear to have the same composition as the matrix; however it is difficult to analyze such small volumes in a much larger matrix. Some of the spherical units appear to be richer in Fe compared to matrix. Additional analyses at low voltage are underway.

Interpretation We suggest that the round and ovoid units illustrated in Figs. 1,2 represent the mineralized remains of bacterial cell bodies. This interpretation is based on the following lines of evidence: (1) In optical view, the tiny spots are relatively uniform in size, usually within a factor of two in diameter. Most are less than 1 micrometer in diameter. In SEM view, the typical size ranges from 0.2 - 1 micrometer with only a small proportion larger than 1 micrometer. This size range is well within the accepted size for most bacteria cells. (2) Some of the cells are attached to each other contiguously, reminiscent of dividing bacteria (Fig. 2). (3) The surface texture of the well-exposed spheres and ovoids is typically complex in detail and closely resembles some mineralized bacterial cells grown in Columbia River Basalt microcosms [3]. (4) A fine filament attached to the end of one ovoid in Fig. 2 is reminiscent of a bacterial fibril [3]. Similar textures are common in the literature of geomicrobiology [4,5,6]. The lacy material found on some of the surfaces and closely associated with the ovoid and round particles closely resembles

mineralized biofilm commonly formed by bacteria. The uneven distribution noted in both the optical and SEM observations can be interpreted as an uneven distribution of cells typical of colonies in confined spaces. If the particles were inorganic chemical precipitates, we might expect a more even distribution throughout the smectite/alteration products.

Origin on Mars or Earth? The embedded objects seem to be contemporaneous with the main mass of the alteration products. Figs. 1,2 illustrate how the products coat and follow the contours of existing bumpy masses. On the other hand, the objects which appear to rest directly on exposed surfaces of alteration products were clearly formed after most if not all alteration product deposition had stopped, which may even indicate terrestrial formation shortly after fall or in the museum. We suggest that this meteorite may contain two generations of bacteria, (if their identification is confirmed), an original Martian generation, and a generation which grew on Earth. The close proximity of the two generations might be explained if the organic Martian remains served as favorable attachment sites for the terrestrial bacteria. Of course, another explanation is that there is only one generation which formed either on Mars or on Earth. While the data support a Martian formation for the alteration products and their embedded small rounded objects, we do not yet have enough information to definitely choose among these options.

Conclusion Nakhla contains variable concentrations of tiny round to ovoid objects which can plausibly be interpreted as bacterial cells in various states of mineralization. Additional tests must confirm this interpretation and distinguish between Martian and terrestrial bacteria. We note in preliminary work that the meteorite Shergotty also contains heterogeneously-distributed submicrometer-sized grains in its vein-filling alteration products. The size, shape, and distribution of these grains in Shergotty closely matches that described for Nakhla.

References [1] Gooding J. L. et al. (1991) Meteoritics 26, 135-143; Bunch T. E. and Reid A. M. (1975) Meteoritics 10, 305-315; Thomas-Keprta K. L. et al. (1998) Geology 26, 1031-1034; Westall F. (1999) J. Geophys. Res. Planets (in press); Banfield F. and Nealson K. H. (editors) (1977) Reviews in Mineralogy, V35, 448p, Min. Soc. Am.; Geomicrobiology (1998), Am. Min. Special Issue, v 83, No. 11-12, Part 2, 1387-1607.

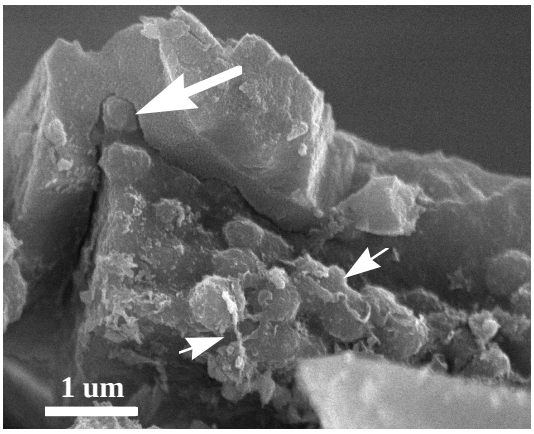


Fig. 1. Deposit characterised by ca. 500 nm-diameter, embedded spheres. The spheres are coated with a flaky substance similar to mineralised biofilm (small arrows). The globular deposit is clearly coated (large arrow) by an amorphous layer with a smectite composition.

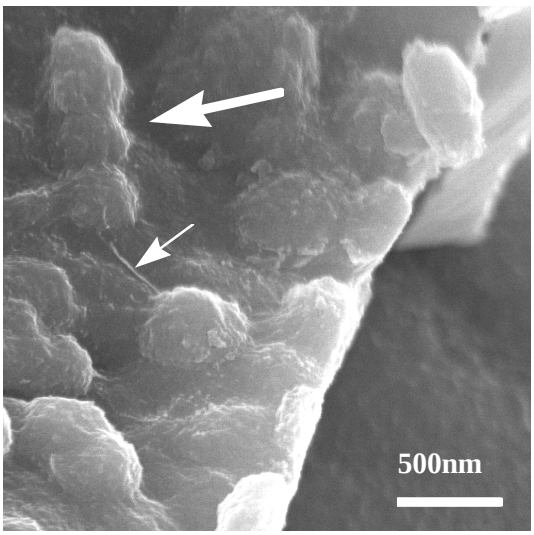


Fig. 2. Ca. 500 nm-diameter, embedded spheres in a deposit cut by a fracture which clearly demonstrated that the spheres are an integral part of the deposit. Joined spheres (large arrow) resemble dividing bacteria. A fine filament (small arrow) running SW of the joined spheres is reminiscent of bacterial fibrils.